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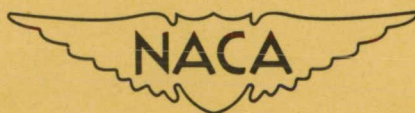
TECHNICAL NOTE

No. 1843

EFFECT OF VARIOUS COMPOUNDS IN USE WITH AIRPLANE ENGINES
UPON FOAMING OF AIRCRAFT LUBRICATING OIL

By J. W. McBain and W. W. Woods

Stanford University



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SUMMARY

Aircraft lubricating oil is contaminated with various materials used in connection with airplane engines or contained in the fuel with which the oil is commonly diluted. Over 60 such materials have each been tested to determine their influence upon the foaming of an aircraft lubricating oil. All but 13 of the compounds have only a small or negligible effect. Some of the 13 compounds are very strong foaming agents and their use might well be discontinued.

INTRODUCTION

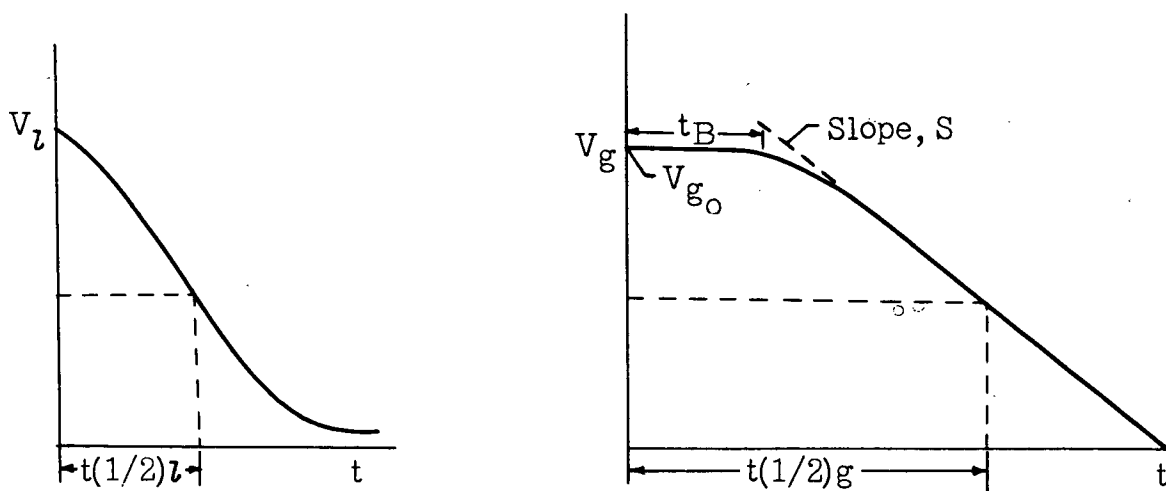
Trouble arising from foaming of aircraft lubricating oil has often been sporadic. Such foaming has been known to displace oil from the circulating system, to impede circulation, or to starve bearings. Certain instances have been traced to contamination of the aircraft lubricating oil. Such contamination may arise from materials used in cleaning the airplane, in preserving the engine from corrosion or rust, in sealing bolts and gaskets, or in packing pumps. Many of these materials come in direct contact with the oil, as, for example, when one of these engine compounds is used to coat a new engine or a repaired engine inside and out to avoid rust or corrosion. Some used oils have been found to foam more than new oils.

Furthermore, it has become customary to facilitate take-off by thinning the oil with fuel, often to a considerable proportion. Hence all the additives commonly used in fuel are directly introduced into the oil in which most additives are, according to specifications, otherwise absent. Since no data were extant on the effect of these materials upon foaming of the lubricating oil, quantitative data are recorded herein and materials which have practically no effect are separated from those which are definitely foamers. Included also are results obtained with some of the chief constituents of aviation gasolines.

This program of research was conducted at Stanford University under the sponsorship and with the financial assistance of the National Advisory Committee for Aeronautics.

SYMBOLS

The symbols used herein were derived to describe curves of the type shown in figures 1 and 2. Their significance is shown on the accompanying idealized diagrams, and the definitions are subsequently given.



where

L_g integral average life of gas in foam (L_g is calculated only for tests at 100°C , table IV)

$R = \frac{t(1/2)l + t(1/2)g}{(t(1/2)l + t(1/2)g)_{\text{std}}}$ (the standard being aircraft lubricating oil alone)

S slope of linearly decreasing part of curve of V_g plotted against time t , expressed as percentage decrease per hour and computed by formula

$$S = \frac{V_{g_0} - V_g}{V_{g_0}} \frac{6000}{t - t_B}$$

t	time, minutes
$t(1/2)_g$	time at which V_g is one-half its initial value V_{g_0} , minutes
$t(1/2)_l$	time at which V_l is one-half its initial value, minutes
t_B	time during which practically no bubbles burst and V_g is constant, minutes
V_g	volume of gas in foam at time t , cubic centimeters
V_l	volume of liquid in foam at time t , cubic centimeters

APPARATUS

The heating apparatus used in the modified Towne test (described in reference 1) was an electric kitchen mixer that includes two glass mixing bowls. The smaller of these bowls was used to contain the oil. The apparatus for the aeration and evacuation test and the apparatus for the bubbling method at 100° C are also described in reference 1.

PROCEDURE FOR TESTING FOAMING

Aeroshell 120 (Wood River) was employed throughout as the test oil, since it is an aircraft lubricating oil containing neither additives nor pour-point depressant.

The method used for room-temperature testing was a modified Towne test (reference 1, p. 33). One hundred cubic centimeters of Aeroshell 120 at room temperature was placed in the bowl of an electric kitchen mixer. The required amount of additive was then added to the oil and the mixture beaten 3 minutes at top speed. The resulting foam was immediately poured into a 100-cubic-centimeter graduated cylinder, time being counted from the moment the top of the foam was level with the 100-cubic-centimeter graduation. The total volume and the volume of liquid drained from the foam were noted at intervals until complete collapse of the foam. From these data the volumes of the gas and of the liquid in the foam at the times of observation were calculated. These volumes were plotted against time, as illustrated in figure 1, and the constants describing the curves were computed.

All the additives were tested in Aeroshell 120 in a concentration of 0.5 percent. Only a few volume readings were made on the collapsing foams of each additive, in order to detect bad foamers with the least expenditure of time. This initial sorting of additives permitted a classification into those practically without influence upon foaming and those that enhance foaming. Those additives with a marked effect on foaming were then studied more thoroughly, and the effect of additive concentration was determined.

Although the foaming of lubricating oils is very sensitive to temperature, it was not expedient to carry out the modified Towne test in a thermostat. Hence, in order to avoid errors due to change in room temperature, an Aeroshell 120 control was run every hour.

Materials enhancing the foaming of Aeroshell 120 at room temperature were tested at 100° C. The method of aeration and evacuation was used (reference 1, p. 34). In two instances, confirmatory foam tests at 100° C were made by the bubbling method (reference 1, p. 35).

A Paranox 56, found to be effective in defoaming Aeroshell 120 at room temperature, was further tested by a prolonged bubbling at 100° C.

PRECISION

The measurement of the drainage of the liquid in a foam $t(1/2)l$ is reproducible to about ± 5 percent. The measurement of foam breakage $t(1/2)g$ is reproducible to about ± 20 percent. The variation is much greater for stable foams because of the inordinately long time that is required for the foam to break, which in certain extreme cases reached 100 to 200 hours. The comparative significance of the results is valid because the range of foam stability is increased many times that of the control oil.

The value of t_b is in most cases determinable to about ± 10 percent. However, in some cases, particularly with very stable foams, the breakage begins so gradually that the time becomes indeterminate.

RESULTS AND DISCUSSION

The additives were classified on the basis of their effect upon the foam stability of Aeroshell 120. The results are presented in tables I to V.

The ratio R was used as the criterion for classification. If R was between 0.6 and 1.3, the additive was concluded to have no serious effect on the foam stability of Aeroshell and would therefore be placed in table I.

The data presented in the tables give parameters to describe curves of liquid drainage and foam collapse for Aeroshell containing the engine additives listed. Illustrative curves for Aeroshell 120 alone and for Aeroshell 120 plus additives having little effect upon the foam stability are reproduced in figure 1. Curves for Aeroshell plus additives greatly stabilizing the foam are reproduced in figure 2.

Additives with Little Effect on Foam Stability

Because most of the additives had no effect on foam stability, table I is excessively large and is therefore subdivided by types of additives:

- (a) Sealing compounds
- (b) Lubricating-oil additives
- (c) Gasoline and gasoline additives

The data in table I were secured without the use of frequent Aeroshell 120 controls. Since $t(1/2)l$ and $t(1/2)g$ for Aeroshell 120 vary considerably with small changes in room temperature, average values were selected to compute R , namely, $t(1/2)l = 38$ and $t(1/2)g = 98$. If R were 1.3 or less, the additive was considered practically harmless and was not further investigated.

Paranox 56 and Paranox 56A, which are listed in table I without any accompanying data, are samples which differ from former commercial samples in that they evidently contain a powerful foam inhibitor. When these additives were present in 5-percent concentration, Aeroshell 120 would not form a foam at all by the modified Towne test. An earlier sample, with the same designation, is listed in tables II to IV and was a foam stabilizer. Spreading tests (on dilute alkali) indicate that the later samples (Paranox 56 and Paranox 56A, table I) contain a very strong surface active agent (such as Gulf additive) which is not present in the earlier samples. The (later) Paranox 56 was also tested by prolonged bubbling at 100° C (table V) and proved to be a defoamer that was effective for at least 13 hours at this temperature.

The effect graphically shown in figure 1 is that the level of the top of the foam does not change appreciably in the first 20 to 60 minutes; that is, the bubbles remain unbroken and no air escapes. Thereafter, they break steadily. Meanwhile, however, the liquid begins to drain at once, and the drainage is almost linear for the greater portion of the lifetime of the foam. Thus, the same quantity of liquid drains per minute regardless of whether the bubbles are breaking. For example, with Antiseize in Aeroshell (fig. 1(b)), the volume of gas in the foam has not sensibly changed when over one-half the liquid has already drained away at a nearly linear rate.

Additives That Enhance Foaming

The compounds causing marked foaming had to be studied in much greater detail to record true values for $t(1/2)?$, t_B , and the slope of the change of volume of gas in the foam after the bubbles began to break. These results are presented in table II. In addition, figure 2 gives in detail two examples of foamers, one for 1.5 percent Paranox 56 and one for 0.1 percent Lamepon 4C. These curves and table II show the following salient facts:

- (1) Drainage may be greatly prolonged, although usually to a lesser extent than film rupture.
- (2) Drainage is no longer approximately linear with time.
- (3) Additives showing low rates of film rupture generally exhibit large values of t_B .
- (4) In a very few cases, low rates of film rupture are accompanied by moderately low values of $t(1/2)?$ and t_B .

Several of the deleterious additives formed tough solid films on draining. These included Lubriplate 130A, Additive for Compounded Diesel Lubricant, and Lamepon 4C. Significantly, Lamepon 4C and Additive for Compounded Diesel Lubricant foam the most at a concentration of 0.5 percent. With Lamepon 4C, the froth does not begin to break until after 20 hours, and even then the rate of breakage is 100 times slower than that of the stock Aeroshell.

All the foamers were still effective at 100° C when the test method was aeration and evacuation (table IV), with two exceptions, namely, Rustban 606 and AE 604. These compounds were further tested at 100° C by the bubbling method. This confirmed that Rustban 606 and AE 604 were not foamers at 100° C, although they were strong foamers at room temperature according to the modified Towne test. As a further check, therefore, both the bubbling test and the aeration and evacuation foam test

were also carried out at room temperature. The results obtained with these two methods showed that Rustban 606 and AE 604 were not foamers, thus contradicting the results of the modified Towne test. This discrepancy may be attributable to the fact that the Towne test produces a foam totally unlike that produced in other test methods. The Towne test foam is extremely wet and, even with Aeroshell 120, creams 20 to 60 minutes before initial breakage, while that produced by other methods commences to break almost immediately. Certain additives previously noted (e.g., Lamapon 4C) form solid films, when time for adsorption is permitted, which greatly delay drainage and/or film rupture. The modified Towne test provides ample time for adsorption from the liquid to the film interface, while the other methods do not. Foams produced by Rustban 606 and AE 604, which were tested by this method, may have formed such structures although they were not detected.

The values of L_g reported in table IV are comparable to the $t(1/2)_g$ values of table I. When the foam collapse is linear, starting at zero time, L_g and $t(1/2)_g$ are identical. The expression L_g is more analytical and is generally used in precise studies. The total life of the foam, also given in table IV, shows whether a stable residual collar of foam remains after most of it has collapsed. In such cases, the total life is greatly more than twice L_g . This is seen to be true for several of the additives in table IV.

SUMMARY OF RESULTS

Over 60 compounds which can gain access to aircraft lubricating oil in airplane operation have been tested for possible effects upon foaming. Most of the compounds have been found practically innocuous, but those listed in this report in tables II, III, and IV, with the uncertain exceptions of Rustban 606 and AE 604, cause excessive foaming and their use might well be avoided. Two samples of Paranox 56, received several months apart, differed in that the first sample was a foam enhancer and the second sample was a powerful foam inhibitor. Likewise a later sample of Paranox 56A was found to be a powerful foam inhibitor.

Stanford University

Stanford University, Calif., January 8, 1945

REFERENCE

1. McBain, J. W., Ross, S., Brady, A. P., Robinson, J. V., Abrams, I, M., Thorburn, R. C., and Lindquist, C. G.: Foaming of Aircraft-Engine Oils as a Problem in Colloid Chemistry - I. NACA ARR No. 4105, 1944.

TABLE I.- ADDITIVES WITH NEGLIGIBLE EFFECT ON FOAMING
AT ROOM TEMPERATURE

[Concentration of additives was 0.5 percent in Aeroshell 120;
test method used was modified Towne test]

Additive	t(1/2) _l	t(1/2) _g	R
Sealing compounds			
Control, Aeroshell 120, without additive	38	98	1
Antiseize	53	119	1.3
Glyptal 1201 Red	39	87	.9
Heldite	38	75	.8
Paraflow	32	68	.7
^a Paranox 12	31	58	.7
^b Paranox 56	No foam		
^b Paranox 56A	No foam		
^c Paranox 441	31	58	.7
^a Paranox 445	53	104	1.2
^d Paratone	29	61	.7
^a Paratone CX	34	63	.7
Permatex No. 1	38	113	1.1
Permatex No. 3	40	111	1.1
Titeseal	39	113	1.1
White Lead Paste	42	101	1.1

^aTested in 5.0-percent concentration.

^bThese are later samples that evidently contain a foam inhibitor.
(See table V.) Compare with first sample of Paranox 56
in tables II, III, and IV.

^cTested in 3.5-percent concentration.

^dTested in 2.0-percent concentration.



TABLE I.- ADDITIVES WITH NEGLIGIBLE EFFECT ON FOAMING
AT ROOM TEMPERATURE - Continued

Additive	t(1/2)l	t(1/2)g	R
Lubricating-oil additives			
Acidless tallow oil	24	79	0.8
Additive X	26	55	.6
Anglamol 40	35	70	.8
Anglamol 73	38	90	.9
Butyl methacrylate Rc 904	35	65	.7
Diesolife B Additive A	40	88	.9
EWS Lard Oil	40	85	.9
Lubrizol 704 conc.	36	83	.9
Perma No. 1	41	90	1.0
Perma No. 2	38	61	.7
Perma No. 5	36	62	.7
Perma No. 6	40	80	.9
Polymerized fish oil	40	105	1.1
Santolube 261	32	94	.9
Santolube 303	39	90	.9
Santolube 394	40	85	.9
Santolube 394 C	40	85	.9
Santopoid S	32	83	.9
Santopour	34	68	.8
Thialkene 7	37	76	.8

TABLE I.- ADDITIVES WITH NEGLIGIBLE EFFECT ON FOAMING
AT ROOM TEMPERATURE - Concluded

Additive	t(1/2) _l	t(1/2) _g	R
Gasoline and gasoline additives			
Alkylate gasoline T-1441	31	92	0.9
Catalytically cracked gasoline T-1933	30	98	.9
100 octane, 4 cc TED/gal T-1769	33	92	.9
Proposed Mod. 130 Gasoline	24	85	.8
100 octane Spec. AN-VV-F781, Amendment 4	26	55	.6
100 octane Spec. AN-F-28	26	55	.6
Ethyl Fluid ^e	52	105	1.1
Ethyl Blue Dye	38	65	.8
Ethyl Orange Dye	40	78	.9
Ethyl Red Dye	41	85	.7
Ethyl Yellow Dye	39	100	1.0

^eEthylene bromide (usual constituent of ethyl fluid) at a concentration of 1.67 percent was subsequently tested at 100° C by the bubbling method and proved to have no effect on the foaming of Aeroshell 120.



TABLE II.- ADDITIVES THAT ENHANCE FOAMING
AT ROOM TEMPERATURE

[Concentration of additives was 0.5 percent in Aeroshell 120;
test method was modified Towne test]

Additive	Slope (percent/hr)	$t(1/2)l$	t_B
Control, Aeroshell 120 without additive	94 to 28	^a 32 to 53	^a 30 to 55
Stan-Add 43A	40.3	48	50
Codel N.C. Additive	26.6	37	32
Diesolife B Additive A	15.2	40	52
Paranox 56 (first sample) ^b	6.1	82	100
Aerolube 20	5.2	130	175
AE 604	4.8	67	90
Tergol Concentrate	4.7	97	150
D 5X Additive A	3.4	117	160
Lubriplate No. 130A	3.3	57	40
Rustban 606	2.7	139	145
^c Standard 31072R	1.9	610	250
Additive for Compounded Diesel Lubricant	1.1	160	500
Lamepon 4C	.4	230	1150

^aRange indicates variation with fluctuating room temperature.

^bCompare with subsequently received defoamed samples of
Paranox 56 and 56A, listed in tables I and V.

^cThis additive was tested in 5-percent concentration, as specified
for its use.



TABLE III.- EFFECT OF CONCENTRATION OF ADDITIVE
ON FOAMING AT ROOM TEMPERATURE

Additive	Concentration (percent)	$t(1/2)l$	t_B	Slope (percent/hr)
AE 604	0	36	36	77.8
	.1	31	25	^a 77.8
	.5	67	90	4.8
Aerolube 20	0	42	50	49.0
	.1	62	75	10.0
	.5	130	175	5.2
Codel N.C. Additive	0	32	30	75.0
	.1	36	35	^a 108.0
	.2	37	60	27.7
	.3	40	68	21.8
	.4	42	26	39.0
	.5	37	32	26.6
	.6	50	50	7.4
Additive for Compounded Diesel Lubricant	0	53	55	28.6
	.1	82	185	3.4
	.5	160	500	1.1
D 5X Additive A	0	53	55	28.6
	.1	80	125	9.1
	.5	117	160	3.4
Diesolife B Additive A	0	42	50	49.0
	.1	40	50	34.7
	.5	40	52	15.2
Lamepon 4C	.1	42	0	1.1
	.5	230	1150	.4
Lubriplate No. 130A	0	43	45	81.3
	.1	44	40	46.7
	.5	57	40	3.3

^aFoam stability is slightly decreased at concentration indicated.

TABLE III.- EFFECT OF CONCENTRATION OF ADDITIVE
ON FOAMING AT ROOM TEMPERATURE - Concluded

Additive	Concentration (percent)	$t(1/2)$	t_B	Slope (percent/hr)
Paranox 56 (first sample)	0	42	50	49.0
	.3	75	85	13.5
	.5	82	100	6.1
	.7	117	226	3.5
	.9	142	221	4.1
	1.1	207	320	4.8
	1.3	190	313	4.2
	1.5	230	190	2.8
Rustban 606	0	51	32	52.5
	.1	70	95	5.2
	.2	105	100	2.7
	.3	107	145	0.9
	.4	147	160	2.8
	.5	139	145	2.7
Stan-Add 43A	0	41	42	93.2
	.1	43	38	53.3
	.2	46	40	48.0
	.3	44	45	52.0
	.4	44	48	34.8
	.5	48	50	40.3
Standard 31072R (25° C)	0	33	21	92.5
	.5	130	100	1.8
	2.0	450	400	2.3
	5.0	610	250	1.9
Tergol Concentrate	0	36	36	77.8
	.1	41	45	6.5
	.5	97	150	4.7



TABLE IV.-- FOAMING AT 100° C OF ADDITIVES THAT ENHANCE
FOAMING AT ROOM TEMPERATURE

[Concentration of additives was 0.5 percent
except where otherwise noted; test method
was aeration and evacuation^a]

Additive	L _g (sec)	Total life (sec)
None, control, Aeroshell 120	0.4	68
^b Rustban 606	22.8	71
^b AE 604	29.7	78
Paranox 56 (first sample)	42.6	158
Tidewater Codel N.C.	44.5	159
Stan-Add 43A	48.1	133
^c Aerolube 20	69.7	810
Tergol Concentrate	108.9	586
Diesolife B Additive A	232.0	1920
D 5X Additive A	334.5	4200
Lamepon 4C	1268	4680

^aStandard 31072R was tested by bubbling at 100° C.

At a concentration of 5.0 percent in Aeroshell 120, average lifetime of gas in foam was 43 min, as compared with 1 to 2 min for Aeroshell 120 alone.

^bThese additives were also tested at 100° C by bubbling method; foam stability by bubbling method was about the same as that of Aeroshell 120 alone.

^cTested at concentration of 0.3 percent.



TABLE V.- EFFECT OF PROLONGED BUBBLING AT 100° C ON AEROSHELL 120
CONTAINING 2.5 PERCENT ^aPARANOX 56 (DEFOAMED)

Bubbling time (hr)	Volume increase (percent)		L _g (sec)	
	Aeroshell 120 alone	Oil plus 2.5 percent Paranox 56	Aeroshell 120 alone	Oil plus 2.5 percent Paranox 56
$\frac{1}{2}$	365	172	78.8	20.1
$1\frac{1}{2}$	436	154	75.6	20.5
$2\frac{1}{2}$	365	154	51.3	21.5
$3\frac{1}{2}$	472	146	77.8	21.4
$4\frac{2}{3}$	454	118	79.6	20.3
6	436	118	65.1	20.3
$6\frac{1}{2}$	436	118	59.1	21.5
9	---	100	----	22.7
11	---	100	----	22.7
$13\frac{1}{4}$	---	100	----	22.7

^aAt a concentration of 5.0 percent Paranox 56 (later sample) in Aeroshell 120, no volume increase was noted after bubbling $1\frac{1}{2}$ hour at 100° C.



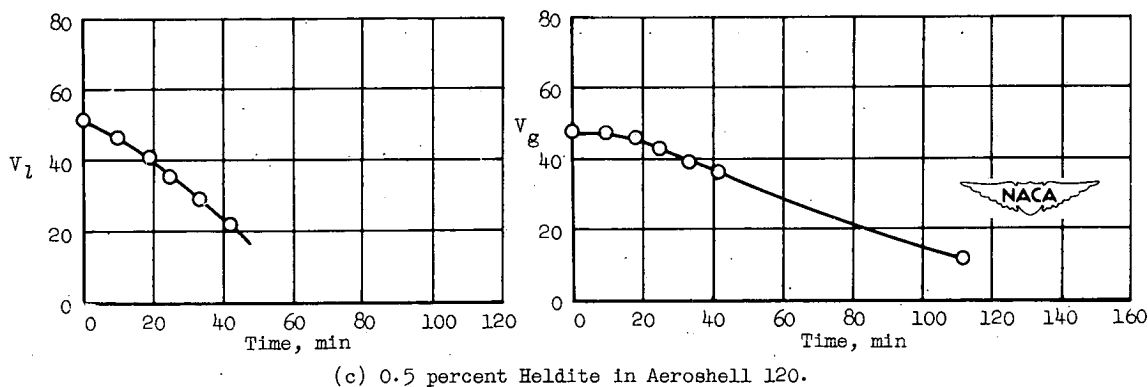
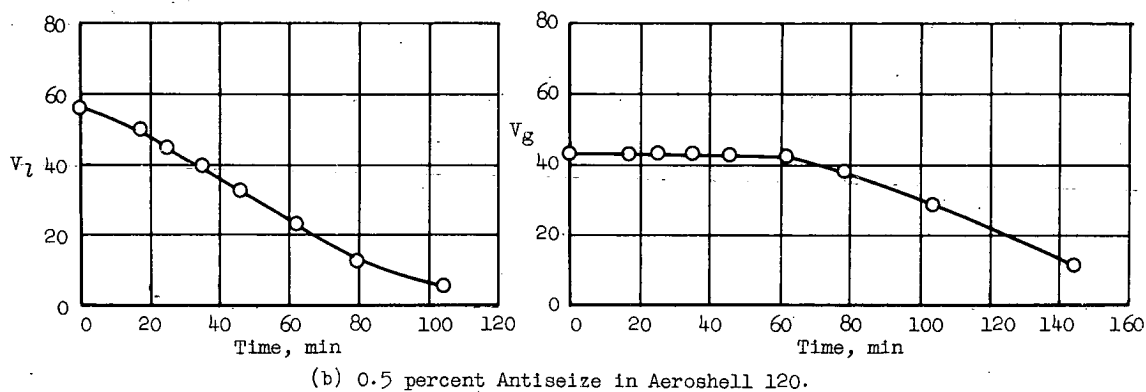
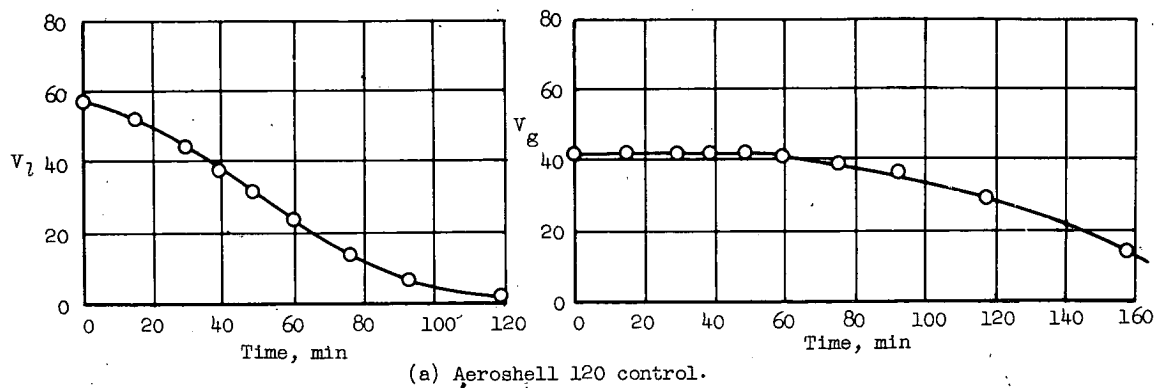
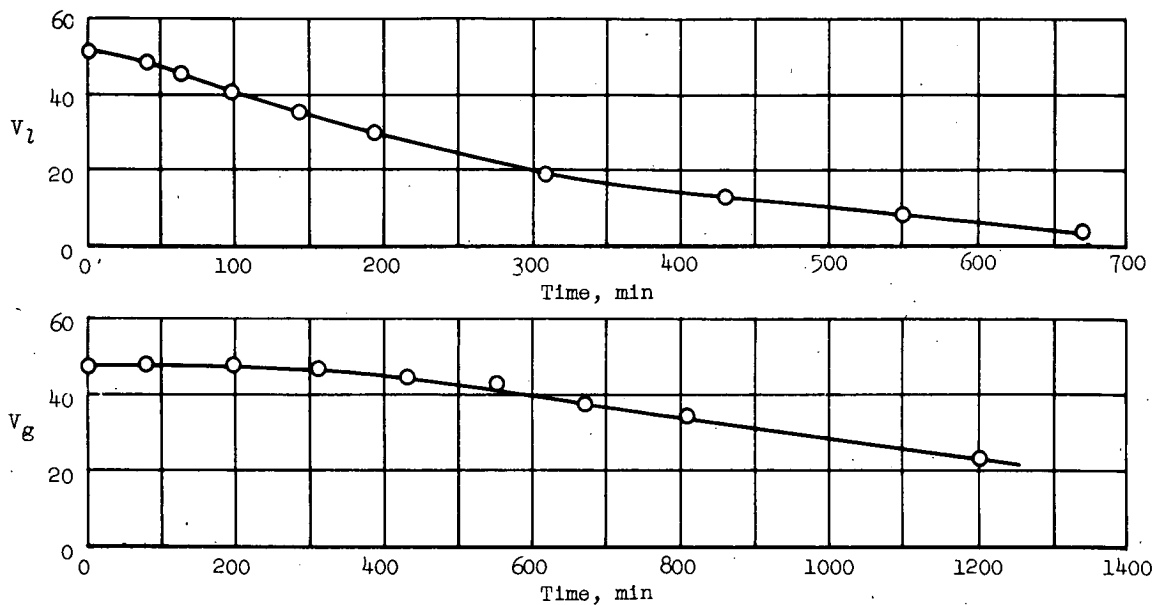
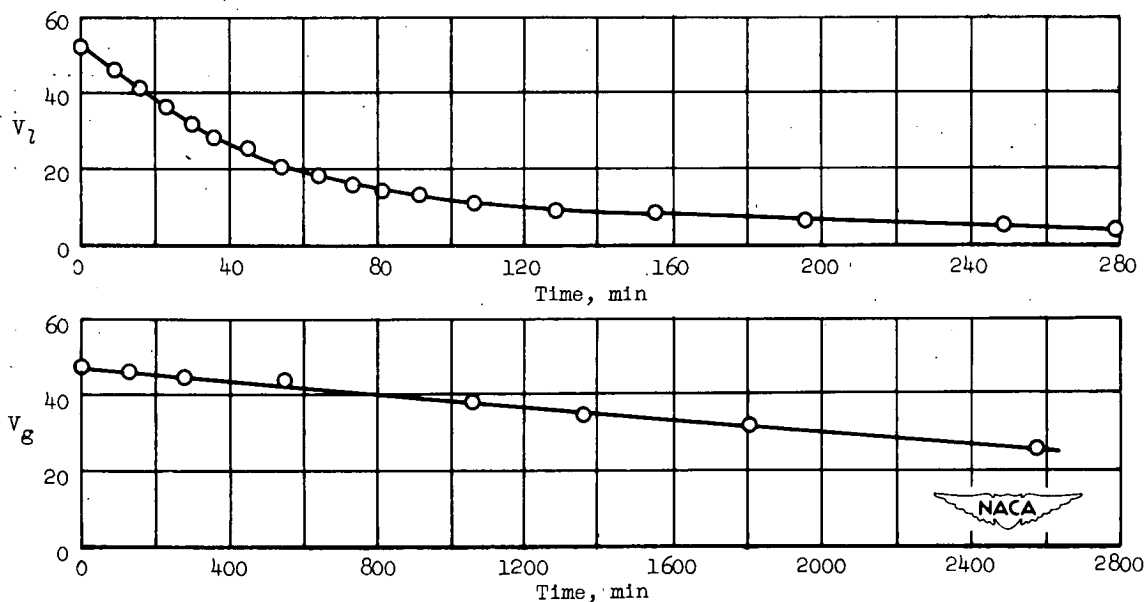


Figure 1.- Volume of liquid in foam V_l and volume of gas in foam V_g .
Original total volume of foam, 100 cubic centimeters.



(a) 1.5 percent Paranox 56 in Aeroshell 120.



(b) 0.1 percent Lamepon 4c in Aeroshell 120.

Figure 2.- Effects of added foamers on change of V_l and V_g with time.